CLAIMS

What is claimed is:

1.   An imaging system, comprising:

    a)   a plurality of subarrays, each having adjacent transducer elements, defining an array of transducers for transmission of energy in a plurality of transmit directions with at least one transmit focal length, for reception of responses to said energy and for output of receive signals;

    b)   a subarray-dependent first filter for spectral modification and interpolation between scan lines for a plurality of receive directions and receive focal lengths from each of said subarrays; and

    c)   a means for combining outputs from said first filter corresponding to each of said subarrays to produce an image.

2.   The image system of claim 1 further comprising a resampler for inserting null scan lines for additional directions between said receive directions for said scan lines from each of said subarrays, wherein said null scan lines are comprised of a set of zeros corresponding to each of said receive focal lengths;

3.   The apparatus of claim 1 further comprising a first array of transducers for transmission of said energy and a second array of transducers for reception of said responses to said energy, wherein said first array is divided into a plurality of subarrays each having adjacent transducer elements, defining said first array.

4.   The apparatus of claim 1 further comprising a first array of transducers for transmission of said energy and a second array of transducers for reception of

said responses to said energy, wherein said second array is divided into a plurality of subarrays, each having adjacent transducer elements, defining said second array.

5. The apparatus in claim 1 wherein a first subarray transmits said energy and a second subarray receives said responses to said energy.

6. The apparatus in claim 1 wherein a first subarray transmits said energy and said first subarray receives said responses to said energy.

7. The apparatus of claim 1 wherein each of said subarrays has same number of said adjacent transducer elements.

8. The apparatus of claim 1 wherein each of said subarrays overlaps adjacent subarrays thereby having transducer elements in common with said adjacent subarrays.

9. The apparatus of claim 8 wherein said overlap of said subarrays is a fixed number of said adjacent transducer elements in each of said subarrays.

10. The apparatus in claim 1 further comprising a look-up table with settings for said first filter for at least some of said subarrays.

11. The apparatus of claim 10 further comprising a calculating means for determining at least some settings for said first filter for at least some of said subarrays.

12. The apparatus of claim 1 wherein said first filter is selected from the group consisting of a 1-dimensional filter, a 2-dimensional filter and a 3-dimensional filter.

13. The apparatus of claim 1 wherein said first filter is varied for at least one of said receive focal lengths for at least one of said subarrays.

14. The apparatus of claim 1 further comprising a second filter for further spectral modification of said outputs from said first filter.

15. The apparatus in claim 14 further comprising a look-up table with settings for said second filter for at least some of said subarrays.

16. The apparatus of claim 15 further comprising a calculating means for determining at least some settings for said second filter for at least some of said subarrays.

17. The apparatus of claim 14 wherein said second filter is selected from the group consisting of a 1-dimensional filter, a 2-dimensional filter and a 3-dimensional filter.

18. The apparatus of claim 14 wherein said first filter is varied for at least one of said receive focal lengths for at least one of said subarrays.

19. The apparatus of claim 1 wherein said first filter is a bandpass filter, said subarrays have same number of said adjacent transducer elements and overlap

3   of said subarrays is equal to half of said number of said adjacent transducer

4   elements in each of said subarrays.

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1   20. The apparatus of claim 1 wherein said energy transmitted is in a range of

2   frequencies selected from the group consisting of acoustic frequencies, optical

3   frequencies, ultrasonic frequencies, sonic frequencies and radio frequencies.

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1   21. The apparatus of claim 1 wherein interpolation in said first filter is varied for at

2   least one of said subarrays.

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1   22. The apparatus of claim 1 wherein said energy transmitted is in a narrowband of

2   frequencies.

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1   23. The apparatus of claim 1 wherein said energy transmitted is in a wideband of

2   frequencies.

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1   24. The apparatus of claim 1 wherein said energy is transmitted at a plurality of

2   transmit focal lengths.

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1   25. The apparatus of claim 1 wherein number of receive directions Q_{S1} in a first

2   plane is

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$$Q_{S1} \geq \frac{4 M_1 d_1}{\lambda_{min}} \sin(\frac{\Theta_1}{2}),$$

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6   where M_1 is number of said adjacent transducer elements in a first dimension of

7   each of said subarrays and said array, d_1 is spacing between each of said

adjacent transducer elements in said first dimension, λ_{min} is minimum wavelength in said energy transmitted, Θ_1 is a first sector angle in said first plane, and where upsampling ratio L_1 in said first plane during interpolation in said first filter is

$$L_1 < \frac{\frac{4N_1 d_1}{\lambda_{min}} \sin(\frac{\Theta_1}{2})}{Q_{S1}},$$

where N_1 is total number of said transducer elements in said array in said first dimension.

26.   The apparatus of claim 25 where number of receive directions Q_{S2} in a second plane is

$$Q_{S2} \geq \frac{4M_2 d_2}{\lambda_{min}} \sin(\frac{\Theta_2}{2}),$$

where M_2 is number of said adjacent transducer elements in a second dimension of each of said subarrays and said array, d_2 is spacing between each of said adjacent transducer elements in said second dimension, λ_{min} is minimum wavelength in said energy transmitted, Θ_2 is a second sector angle in said second plane, and where upsampling ratio L_2 in said second plane during interpolation in said first filter is

$$L_2 < \frac{\frac{4N_2 d_2}{\lambda_{min}} \sin(\frac{\Theta_2}{2})}{Q_{S2}},$$

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15   where N_2 is total number of said transducer elements in said array in

16   said second dimension.

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1   27.   A method of image reconstruction comprising the steps of:

2   a)   transmiting energy in a plurality of transmit directions with at least one

3   transmit focal length with a subarray having adjacent transducer elements in an

4   array of transducers, receiving responses to said energy and outputting receive

5   signals with said subarray;

6   b)   spectrally modifying and interpolating between scan lines for a plurality of

7   receive directions and receive focal lengths from said subarray with a first

8   subarray-dependent filter;

9   c)   combining output from said first filter using a means to produce an

10   intermediate result; and

11   d)   repeating steps a)-c) for a plurality of subarrays that define said array to

12   produce a reconstructed image.

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1   28.   The method of claim 27 further comprising the step of upsampling by inserting

2   null scan lines for additional directions between said receive directions for said

3   scan lines from said subarray, wherein said null scan lines are comprised of a

4   set of zeros corresponding to each of said receive focal lengths;

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1   29.   The method of claim 27 wherein said transmitting of said energy and said

2   receiving said response to said energy are performed by a first subarray.

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1 30. The method of claim 27 wherein said transmitting of energy is performed by a
2 first subarray and said receiving said responses to said energy is performed by
3 a second subarray.
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1 31. The method of claim 27 wherein each of said subarrays has same number of
2 adjacent transducer elements.
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1 32. The method of claim 27 wherein each of said subarrays overlaps adjacent
2 subarrays thereby having transducer elements in common with said adjacent
3 subarrays.
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1 33. The method of claim 32 wherein said overlap of said subarrays is a
2 fixed number of said adjacent transducer elements in each of said
3 subarrays.
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1 34. The method of claim 27 further comprising the step of looking up settings for
2 said first filter in a look-up table for at least some of said subarrays.
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1 35. The method of claim 34 further comprising the step of calculating at
2 least some settings for said first filter for at least some of said subarrays
3 with a calculating means.
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1 36. The method of claim 27 further comprising the step of varying said first filter
2 for at least one of said receive focal lengths for at least one of said subarrays.
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1 37. The method of claim 27 further comprising the step of spectrally modifying
2 said outputs from said first filter with a second filter.

38. The method of claim 37 further comprising the step of looking up settings for said second filter in a look-up table.

39. The method of claim 38 further comprising the step of calculating at least some settings for said second filter for at least some of said subarrays with a calculating means.

40. The method of claim 37 further comprising the step of varying said second filter for at least one of said receive focal lengths for at least one of said subarrays.

41. The method of claim 27 wherein transmitting said energy is in a range of frequencies selected from the group consisting of acoustic frequencies, optical frequencies, ultrasonic frequencies, sonic frequencies and radio frequencies.

42. The method of claim 27 wherein transmitting said energy is in a narrowband of frequencies.

43. The method of claim 27 wherein transmitting said energy is in a broadband of frequencies.

44. The method of claim 27 wherein number of receive directions Q_{S1} in a first plane is

$$Q_{S1} \geq \frac{4 M_1 d_1}{\lambda_{min}} \sin(\frac{\Theta_1}{2}),$$

where M_1 is number of said adjacent transducer elements in a first dimension of each of said subarrays and said array, d_1 is spacing between each of said adjacent transducer elements in said first dimension, λ_{min} is minimum wavelength in said energy transmitted, Θ_1 is a first sector angle in said first plane, and where upsampling ratio L_1 in said first plane in said interpolating is

$$L_1 < \frac{\frac{4N_1 d_1}{\lambda_{min}}\sin(\frac{\Theta_1}{2})}{Q_{S1}},$$

where N_1 is total number of said transducer elements in said array in said first dimension.

45. The method of claim 44 wherein number of receive directions Q_{S2} in a second plane is

$$Q_{S2} \geq \frac{4M_2 d_2}{\lambda_{min}}\sin(\frac{\Theta_2}{2}),$$

where M_2 is number of said adjacent transducer elements in a second dimension of each of said subarrays and said array, d_2 is spacing between each of said adjacent transducer elements in said second dimension, λ_{min} is minimum wavelength in said energy transmitted, Θ_2 is a second sector angle in said second plane, and where upsampling ratio L_2 in said second plane in said interpolating is

$$L_2 < \frac{\frac{4N_2 d_2}{\lambda_{min}} \sin(\frac{\Theta_2}{2})}{Q_{S2}},$$

where N_2 is total number of said transducer elements in said array in said second dimension.

46.   The method of claim 27 further comprising the step of varying said interpolating in said first filter for at least one of said subarrays.

47.   The method of claim 27 further comprising the step of repeating steps a)-c) for at least some of said subarrays and averaging said intermediate result corresponding to each repetition prior to step d) thereby improving signal-to-noise ratio.

48.   The method of claim 27 further comprising the step of repeating step a) for at least some of said subarrays and averaging said receive signals corresponding to each repetition prior to step b) thereby improving signal-to-noise ratio.

49.   The method of claim 27 further comprising transmitting said energy at a plurality of transmit focal lengths.